VISUAL CHARACTERISTICS OF NAVY DIVERS

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SUMMARY PAGE

Problem

To profile the visual status of Navy divers after several years of duty.

FINDINGS

Navy divers retain their excellent vision after several tours of duty. Their mean acuity is 20/20, their depth perception and color vision are excellent, a larger percentage than would be expected exhibit normal phorias, and their mean point of accommodation exhibits a normal decline with age.

APPLICATION

These findings are relevant to the documentation of the effects of military service on health.

ADMINISTRATIVE INFORMATION

This investigation was conducted in conjunction with the Longitudinal Health Study. This report was submitted for review on 17 February 1981 and approved for publication on 12 May 1981. It has been designated as NavSubMedRschLab Report No. 949.

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ABSTRACT

The results of a series of visual tests given to 153 divers are presented. They show that the divers, who are a highly select population with regard to vision, remain so throughout their tours of duty. Their mean acuity is 20/20, their depth perception and color vision are excellent, a larger percentage than would be expected exhibit normal phorias, and their mean point of accommodation exhibits a normal decline with age. In addition, the mean calibres of their retinal arteries and veins and the artery/vein ratios are completely normal. Compared with submariners, the divers have significantly better acuity at distance, better depth perception and less refractive error. Their visual performance, however, is worse in certain respects than that for unselected samples of the population from previous generations.

INTRODUCTION

The Naval Submarine Medical Research Laboratory routinely subjects all divers who participate in its diving investigations to a thorough medical examination. This serves primarily to identify visual problems and medical risks beforehand and ensure that the men are fit to participate in the dive. It also serves to provide normative data on visual health. In addition, these examinations add to the store of information accumulated in the former Longitudinal Health Study, an investigation of the health of submariners and divers which was begun out of concern for the effects of the unusual and specialized environments in which these men work.

A progress report detailing the visual characteristics of the first 750 submariners has been presented,[1] as well as a description of the entire program and its rationale[2] and the computer program for data storage and analysis.[3] A subsequent investigation compared the vision of submariners with a group of national guardsmen, two groups who were quite similar except for submarine experience.[4]

The analysis of the visual characteristics of the submariners yielded a picture of the average submariner as a healthy young man whose distance acuity is somewhat below average and who has more myopia than normal, in conformity with all the previous investigations of submariners[5-9] and various theoretical positions on the genesis of myopia.[10,11]

Navy divers are selected even more rigorously for visual status than are submariners, and it is of interest to monitor their visual status after several years of duty. This report presents the results of the visual tests given to 153 divers.

THE TESTS

1. The Ortho-Rater. This is a device used for mass screening of visual acuity. It provides a rapid measure of both monocular and binocular acuity under controlled lighting at both near (13 inches) and far (simulated 26 feet) viewing distances. The acuity test is a checkerboard which the subject must differentiate from three gray squares of equal size and mean brightness. Also included in the Ortho-Rater are measures of phoria, both vertical and horizontal, for near and far distances, and a test of depth perception based upon binocular disparity.

2. Accommodation. A simple ruler, along which a target with a fine line can be moved, is used to test the ability of the eye to accommodate or focus at close distances. Measurements are made of the distance from the cornea to the plane of clear focus. Four separate determinations of this near point are made, and the average distance is expressed in diopters. There is a general relationship between age and the ability to accommodate, younger individuals being able to exert greater dioptric power.

3. Refraction. A standard manifest refraction is performed on the right eye using a Bausch & Lomb Phoropter and an American Optical Co. Projecto-Chart. The current prescription is measured with an American Optical Company Lensometer.

4. Fundus photographs. A Zeiss Ikon Fundus camera is used to photograph the right eye. The procedure for measuring the retinal vessels has been described previously.[12] The same field of view, which includes the optic disc and the temporal vessels in the lower field, is always measured at the same location. The artery/vein ratio is one indication of hypertension. In addition, a photograph of the anterior portion of the eye--commonly called the red reflex--is taken and any abnormality noted. Since the pupil must be dilated for the fundus photographs, no pictures are attempted for men whose ocular pressure is abnormal.

5. Color vision. The men's color vision is assessed with three tests: the American Optical Co. Pseudo-Isochromatic Plates, the Hecht-Shlaer or Nagel Anomaloscope, and the Farnsworth-Munsell 100-Hue Test. The plates and the anomaloscope are routine screening tests for color vision defects; taken together, a determination is made of the presence and type of defect. The 100-Hue test is a simple but sensitive measure of the ability to discriminate colors. It consists of about 90 plastic cups on which a wide array of different colors are mounted. The colors, which encompass the color circle from red through yellow, green, blue, purple, and back to red, are divided into four panels with two endpoints each. The subject's task is to arrange the colors in the order of regular color series from one endpoint to the other. The test has been extensively used to separate persons with normal color vision according to their ability to discriminate hues, to measure the color confusions of color defective individuals, and to study acquired deficiencies of color vision.[13,14]

TEST ADMINISTRATION

Volunteers for the test program are scheduled to take the entire series of tests in one and one-half days. Since some of the tests in the general battery are relatively time-consuming, it is not possible to give all the tests to all the men. Therefore, the men are randomly assigned to one of two groups. One group, comprising about 40 percent of the men, receives all the tests; the second group is given all but the color vision and the fundus photography. These data began in 1973.

RESULTS

Acuity

The average results for the divers on the various tests in the Ortho-Rater are given in Table 1. Their average binocular acuity at distance was 1.01. A value of 1.0 represents 20/20 Snellen acuity. The divers are, therefore, at that level on the average, indicating that most men have good vision. The actual distributions of the various binocular acuity levels at distance are given in Table 2 and Fig. 1. There is a marked preponderance of acuities in the highest levels.

The average binocular acuity at near is even higher: 1.11, approaching the highest acuity level measurable in the Ortho-Rater. The fact that mean acuity is higher at near indicates that most of the small number of men who do not have 20/20 vision are slightly myopic, or nearsighted. In general, their acuity is excellent.

Phoria

The measures of vertical phoria show only very small amounts of deviation, as is typical of the general population. Lateral phorias tend to be greatly exophoric at near and slightly esophoric at far, according to the norms given in the Ortho-Rater manual.[15] The distributions of phorias are given in Table 3. The percentage of men falling outside the range encompassing 67% of the population is approximately what it should be for lateral phoria at far and vertical phoria at near; it is actually somewhat less than expected for lateral phoria at near and vertical phoria at far.

Depth Perception

The average depth perception score was 5.0 out of a possible 9 (Table 1). The distribution is bimodal, as shown in Fig. 2. Half of the men have a score of 90% or greater, about as good as is possible on the test; about 15% of the divers have virtually no stereoacuity.

Near Point of Accommodation

Table 4 gives the average results for the remaining measures and some auxiliary data. The average near-point of accommodation is 7.1 diopters for the divers. The relationship to age is shown in Fig. 3. The younger the man, on the average, the greater the power of accommodation, of course.

Refractive Error

The average amount of refractive error for the divers was -0.32 diopters. Figure 4 gives the distribution of the errors. Most of the men have a small amount of error; the modal point is between zero and -0.49 diopter, and the distribution is skewed towards the minus, or myopic, side, as was indicated by the near and far acuity data. More than 17% of the divers have more than one diopter of myopia, and only 3% of them have more than one diopter of hyperopia.

Fundus Photography

The mean retinal artery calibre was 100.7 ±16.7 micra; the mean vein calibre was 139.5 ±17.2 micra. The artery/vein ratio was .72 ±0.11. These values are completely normal and almost exactly the same size as was found in the previous investigation.[4]

Color Vision

The color vision tests were administrated to 47 divers. The results for the pseudo-isochromatic plates are given in Table 5. These plates are used primarily to categorize an individual as color normal or color defective. The criterion for passing the test is four or fewer errors in identifying the figures on the plates. On this basis, 95% of the divers were classified as color normal. The vast majority had no errors at all.

Two divers were classified as color defectives, having made more than 7 errors. They were further classified according to the type and degree of defect by the additional tests from the NSMRL test battery.[16] The anomaloscope is used primarily to classify color defectives for type and degree of defect. For example, a complete dichromat will match the entire range of hues from

green through red with the standard yellow; protanopes require a large increase in the amount of red in the match. Color normals make matches which fall in a very restrictive range, and this was true for the color normals in this group. The two color defectives were classified as mild. Mild defectives are acceptable as divers.

The results on the 100-Hue test for the color normals are given in Table 6, which gives the average errors for each of the four panels on the test. The mean number of errors was 34.3. These error scores are somewhat better than those made by Verriest's[14] sample of 20- to 30-year-old men, whose mean error score was 43±33. The distribution of errors is quite comparable, however; Verriest's data also show the most errors in the blue-green region (caps 43-50) for all age-groups. The percentage of men obtaining various error scores is shown in Fig. 5.

As expected, the two color defectives made more errors on the test. They had error scores of 72 and 116. It should be noted, however, that it is not the total errors but rather the pattern of errors that is the criterion of defective color vision on this test.[13] In fact, some color normals with poor discrimination make more errors than color defectives,[17] but the distribution of errors made by color normals is random.

DISCUSSION

These results show that the divers, who are a highly select population to begin with, have remained so on the average through their tours of duty. Their mean acuity remains 20/20, a larger percentage of them exhibit normal phorias than would be expected, and their depth perception and color vision are excellent. Only their average ability to accommodate has inexorably declined with age, apparently to the degree that is to be expected for men their age.

It is of some interest to compare these results with those of submariners whose visual characteristics have already been documented.[1] The divers have significantly ($p < .01$) better acuity at distance (although not at near), better depth perception ($p < .02$), and less ($p < .01$) refractive error. There are no differences in color perception between the divers and submariners, or in the diameters of their retinal blood vessels. There are also no differences between their measures of phoria or the changes in near point of accommodation with age.*

Both groups may be compared with data that is available for the general population. A 1960 survey of the acuity of the adult, civilian, non-institutionalized population showed that almost 80% of the men under 45 years of age had unaided binocular acuity of 20/20 or better.[18] This is the same figure for the highly select divers in this sample, but it is only 63% for the submariners.

The older studies of the distribution of refractive error in the general population reported average values of around +.5 diopters for

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* We thank Drs. Charles Bond and Thomas Santoro for this analysis of the significance of differences between the two sets of near points.

young adults without pathology.[19-23] The average refractive error for the divers is -.3 diopters, which is appreciably worse than the values reported in the older studies. However, the value for the divers is still significantly better than that for the submariners, -.7 diopters; the submariners, of course, are a less highly selected population than the divers. The incidence of myopia is also much higher than in the older surveys, and the near points of accommodation of both groups is decidedly poorer than those of the subjects of Duane's[24] classic study. The comparison shown in the report on the 750 submariners[1] also holds for the divers. Finally, both groups are more esophoric at far and exophoric at near than the sample tested in 1948 at the San Diego Fair.[25]

Thus, although the present sample of divers constitute a highly select sample of men as far as vision is concerned, it is clear that their mean visual performance is in certain respects worse than that for unselected samples of the population from previous generations. Further, in the comparison study between submariners and national guardsmen,[4] two groups of men who were very comparable except for submarine experience, it was found that the differences, although statistically significant, were quite small in comparison with the differences between submariners and previous generations. Taking all these results into consideration, we are led to the conclusion that there has been a degradation in the visual capacity of American young men in the past generation, changes which mimic those were first noticed among submariners and which would appear to be the result of changes in national life-style or the national environment. Whatever the factors responsible for the decline in vision, we suggest once again that although they may be operating more effectively on submariners, the present data for divers indicate that they are operating on the entire population.

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Table 1

Average values on the Ortho-Rater tests

Test	Mean	Standard deviation
Acuity at distance (1/min. visual angle)		
Binocular	1.01	.23
Right eye	.94	.26
Left eye	.96	.23
Near acuity		
Binocular	1.11	.16
Right eye	1.06	.18
Left eye	1.08	.18
Phorias (prism diopters)		
Vertical - far	.11	.41
Vertical - near	.12	.41
Lateral - far	.26 (eso)	2.41
Lateral - near	-5.28(exo)	4.28
Depth Perception		
Ortho-Rater score (out of 9)	5.00	2.84
Fry-Shepard Scale	78.2%	33.9 %

Table 2

Percentage of men at each acuity level

Acuity (1/min vis. angle)	Distant			Near		
	Binocular	Right	Left	Binocular	Right	Left
0	0.0	0.0	0.0	0.0	0.0	0.0
.1	0.0	0.0	1.3	0.0	0.0	0.0
.2	0.0	1.3	0.6	0.0	0.0	0.0
.3	0.6	2.6	0.0	0.0	0.0	0.6
.4	0.6	0.6	2.6	1.3	1.3	1.3
.5	0.6	5.2	1.3	0.6	2.0	1.3
.6	4.3	3.3	2.6	0.6	1.3	0.0
.7	3.3	7.2	9.8	2.0	1.3	2.0
.8	7.6	6.5	5.2	3.9	4.6	5.9
.9	10.5	10.5	13.1	2.6	9.8	6.5
1.0	14.4	19.0	19.6	11.8	14.4	11.8
1.1	24.8	19.0	20.9	16.3	22.9	20.3
1.2	33.7	24.2	22.9	60.8	42.5	50.3

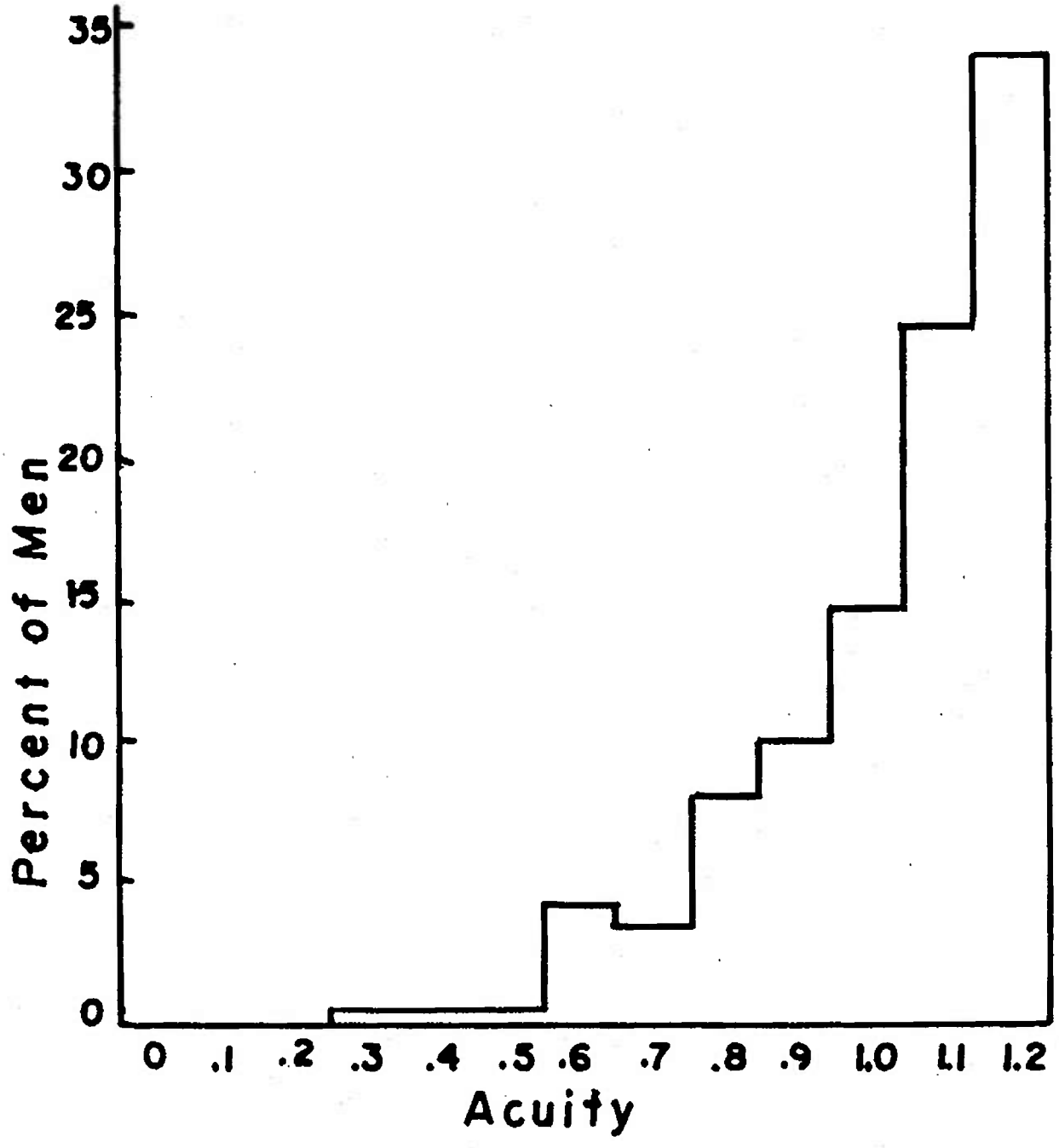

Fig. 1. The distribution of binocular visual acuity at distance.

Table 3

Percentage of men with varying amounts of phoria

	Vertical			Lateral			
	Prism Diopter	Far	Near	Prism Diopter	Far	Prism Diopter	Near
LH	2.0	0.0	0.0	8.0	1.3	6.0	1.3
	2.0	0.6	0.0	7.33	0.6	6.0	0.0
	1.5	1.3	0.6	6.33	1.3	4.5	1.3
	1.0	2.6	1.3	5.33	0.6	3.0	0.6
	0.5	12.4	24.8	4.33	3.3	1.5	2.6
	0.17	52.3	45.8	3.33	4.6	0.0	9.2
RH	0.17	20.3	18.3	2.33	12.4	-1.5	14.4
	0.5	8.5	7.2	1.33	16.3	-3.0	9.2
	1.0	1.3	0.0	0.33	19.6	-4.5	14.4
	1.5	0.6	1.3	-0.66	19.0	-6.0	11.1
	2.0	0.0	0.6	-1.66	6.5	-7.5	14.4
				-2.66	6.5	-9.0	7.8
				-3.66	3.3	-10.5	4.6
				-4.66	2.0	-12.0	2.6
				-5.66	1.3	-13.5	2.0
				-6.66	1.3	-15.0	4.6

Normal values are indicated by dashed lines; limits of 2/3 of population by solid lines, according to Ortho-Rater Manual.

LH = Left Hyperphoria

RH = Right Hyperphoria

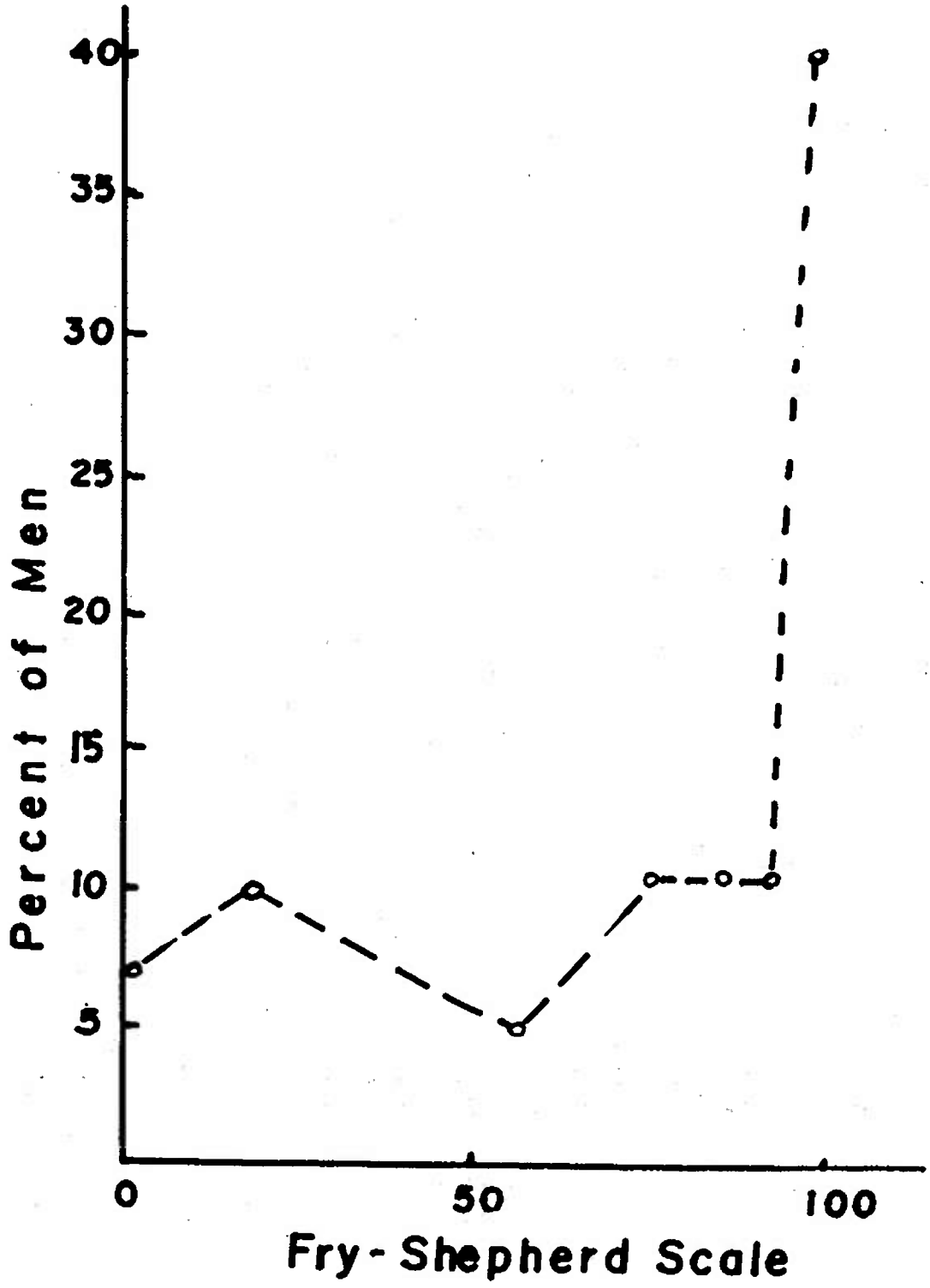

Fig. 2. The distribution of scores on the depth perception test.

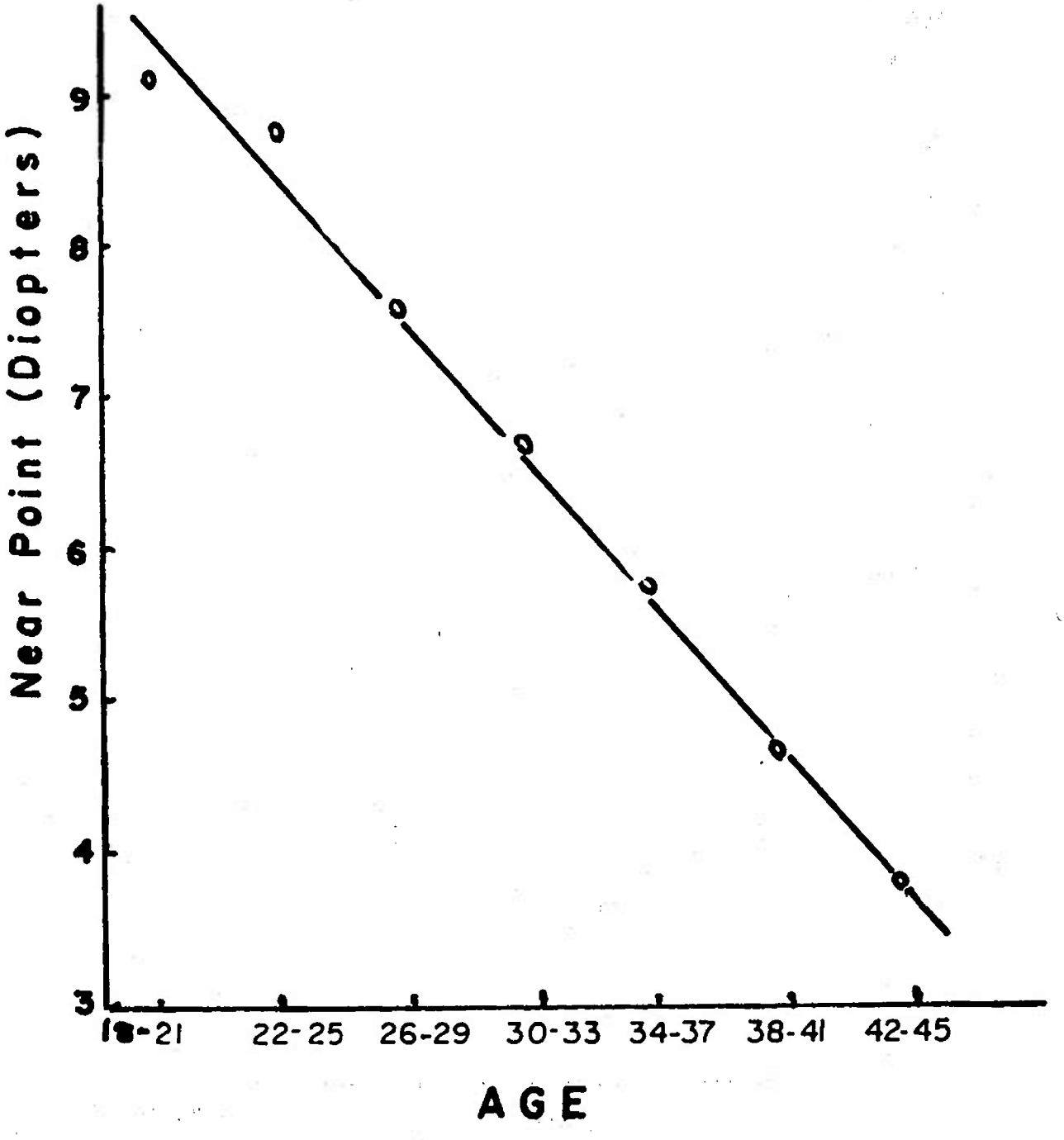

Fig. 3. The near point of accommodation as a function of age.

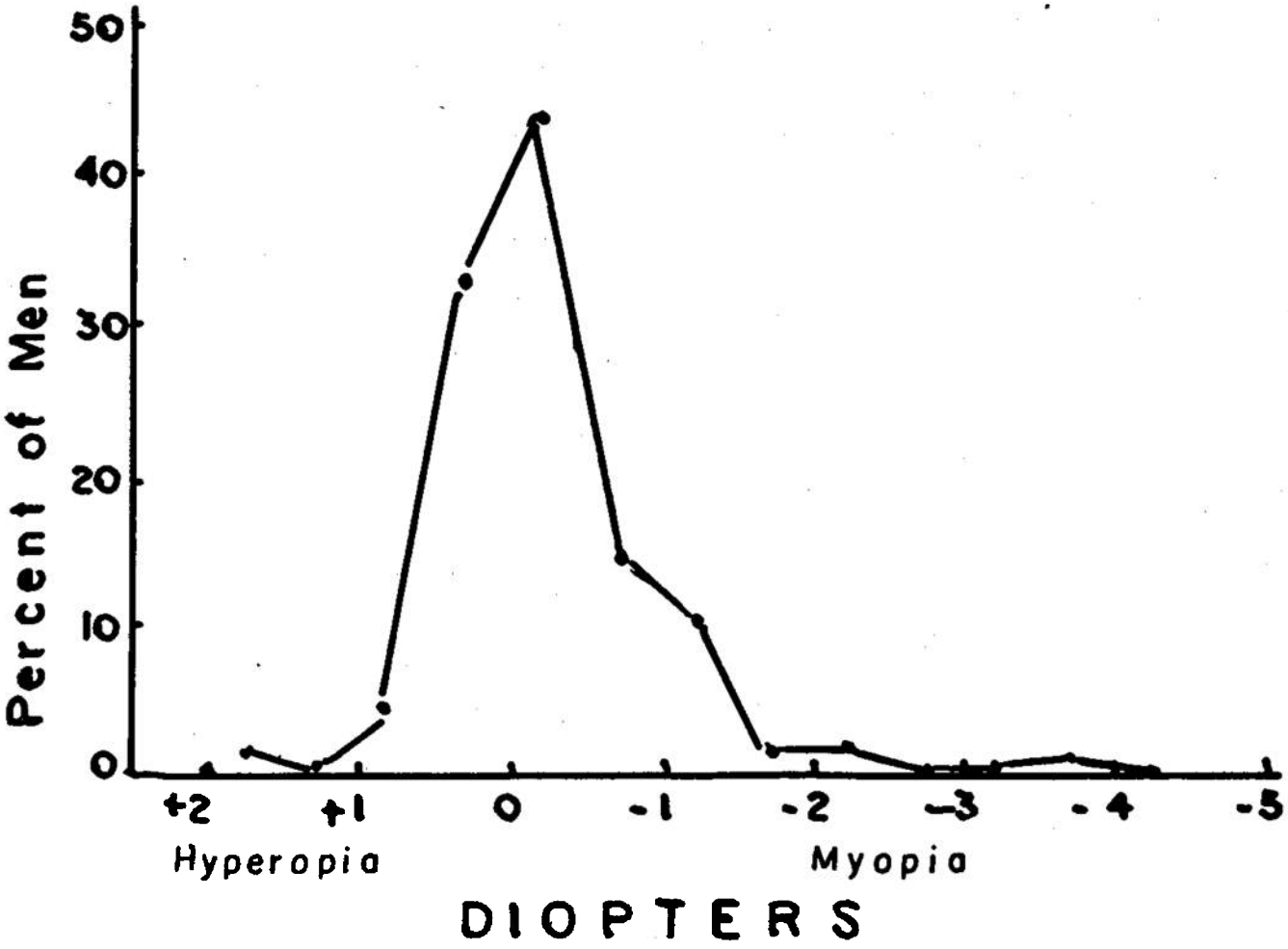

Fig. 4. The distribution of refractive errors.

Table 4

Average accommodation, refractive error, and age

	Mean	Standard deviation
Age (years)	28.28	5.98
Accommodation (in diopters)	7.1	2.1
Refractive error (in diopters spherical equivalent)	-0.32	0.94

Table 5

Results on Pseudo-Isochromatic Plates

Number of Errors	Number of Men	% of Color Normals
0	37	92.5
1	2	5.0
2	1	2.5
3	0	0.0
4,5,6	0	0.0
7-14	2	

Table 6

Mean number of errors on the Farnsworth-Munsell

100-Hue Test by the color normals

Panel #	Cap #	Hues	Mean Error	Standard deviation
1	85-21	red to yellow	6.3	7.0
2	22-42	yellow to blue-green	8.1	7.6
3	43-63	blue-green to purple-blue	10.7	8.5
4	64-84	purple-blue to red	9.2	8.3
	Total		34.3	26.7

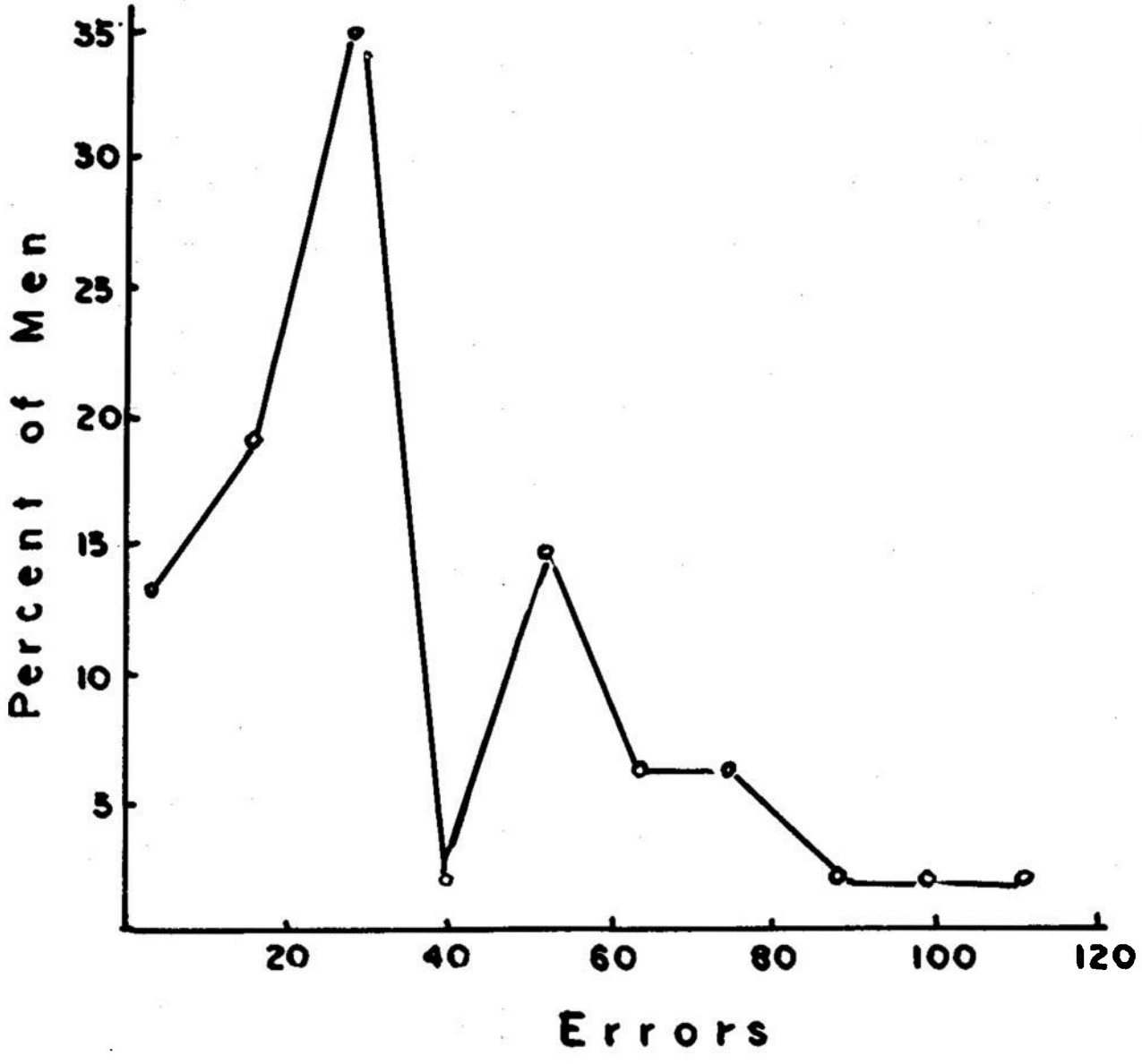

Fig. 5. The distribution of errors onthe 100-Hue test of color vision.

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The results of a series of visual tests given to 153 divers are presented. They show that the divers, who are a highly select population with regard to vision, remain so through their tours of duty. Their mean acuity is 20/20, their depth perception and color vision are excellent, an larger percentage than would be expected exhibit normal phorias, and their mean point of accommodation exhibits a normal decline with age. In addition, the mean calibres of their retinal arteries and veins and the artery/vein ratios are completely normal. Compared with submariners, the divers have

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